Table 6A: CHI-SQUARE TEST OF INPRI AS WHITE NOISE PROCESS

```
DEPENDENT VARIABLE   15      INPRI
FROM  1952:  1  UNTIL  1983:  1
OBSERVATIONS               32       DEGREES OF FREEDOM      31
R**2              .00000000      RBAR**2           .00000000
SSR           115406.48          SEE           61.014667
DURBIN-WATSON  2.13266223
Q(   15)=    7.77015        SIGNIFICANCE LEVEL  .932666
LABEL      VAR  LAG    COEFFICIENT   STAND. ERROR    T-STATISTIC
*******    ***  ***    ************  ************    ************
CONSTANT    0    0     162.3445       10.78597        15.05145
```

Table 6B: AUTOCORRELATIONS FOR INPRI (RELATIVE INPUT PRICE VARIABLE)

34 Observations, From 1950 to 1983

LAG	ESTIMATE	z VALUE
1	-.065129	-.36
2	-.180077	-.97
3	.145610	.74
4	-.087320	-.49
5	.160926	.81
6	-.208028	-1.17

Table 7: SIMULATION WITH ACTUAL RULE

ENTRY	SOIL MGMT	SOIL DPTH	ACP
8	1.59219	11.4589	.284177
9	1.63582	11.4373	.476799
10	1.58828	11.4188	.262810
11	1.57601	11.3974	.392827
12	1.66572	11.3755	.444937
13	1.66991	11.3596	.398986
14	1.56801	11.3442	.273326
15	1.44052	11.3223	.170683
16	1.43946	11.2924	.250670
17	1.51909	11.2627	.315329
18	1.58411	11.2386	.360088
19	1.54211	11.2189	.256743
20	1.47559	11.1967	.227283
21	1.47898	11.1704	.259528
22	1.52195	11.1447	.301103
23	1.42719	11.1220	.116825
24	1.31839	11.0934	.842970E-01
25	1.40527	11.0581	.255672
26	1.39140	11.0288	.100784
27	1.34724	10.9989	.140116
28	1.41632	10.9665	.229675
29	1.43804	10.9389	.190166
30	1.47541	10.9130	.277749

Table 8: SIMULATION WITH OPTIMAL RULE

ENTRY	SOIL MGMT	SOIL DPTH	ACP
7	2.86322	11.6141	.754200
8	2.20055	11.6994	.434701
9	2.99948	11.7409	.835244
10	1.97217	11.8337	.344028
11	2.76963	11.8590	.740128
12	2.56516	11.9356	.639075
13	2.30575	11.9982	.507979
14	2.00804	12.0433	.362712
15	2.01840	12.0686	.356068
16	2.47367	12.0943	.580694
17	2.46050	12.1492	.570345
18	2.38845	12.2027	.533766
19	1.95337	12.2509	.320581
20	2.08211	12.2704	.383581
21	2.22128	12.2980	.452641
22	2.25128	12.3344	.464268
23	1.64900	12.3723	.165114
24	1.96104	12.3708	.310359
25	2.48522	12.3895	.568315
26	1.70089	12.4419	.186482
27	2.10974	12.4430	.382252
28	2.22366	12.4705	.436364
29	1.91962	12.5052	.293423
30	2.17939	12.5197	.421077

Table 9: YEARLY VALUE OF THE REGULATORY OBJECTIVE FUNCTION (SIMULATION)

ENTRY	OPTIMAL RULE	ACTUAL RULE
8	.251068	.226517
9	1.33035	.209264
10	.499167	.264097
11	.916393	.214680
12	.340501	.117353
13	.128979	.113324
14	.043652	.219232
15	.042961	.334782
16	.328585	.327417
17	.212282	.239912
18	.153661	.177106
19	.096046	.231722
20	.014939	.276800
21	.058814	.273608
22	.063421	.232102
23	.308045	.398256
24	.045092	.466774
25	.372879	.414364
26	.390611	.419947
27	.091205	.429297
28	.056073	.357253
29	.048663	.319021
30	.065841	.291044
mean	.252899	.284950

FIGURE 1: SHOCK TO SOIL MANAGEMENT

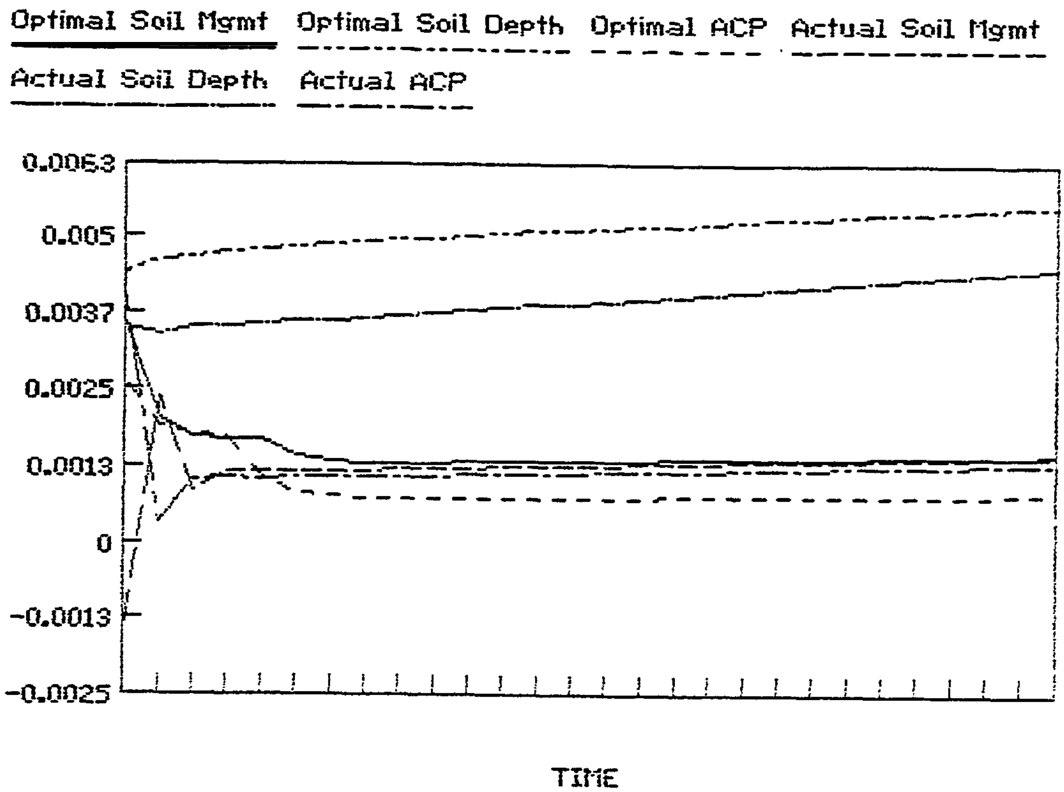


FIGURE 2: SHOCK TO SOIL DEPTH

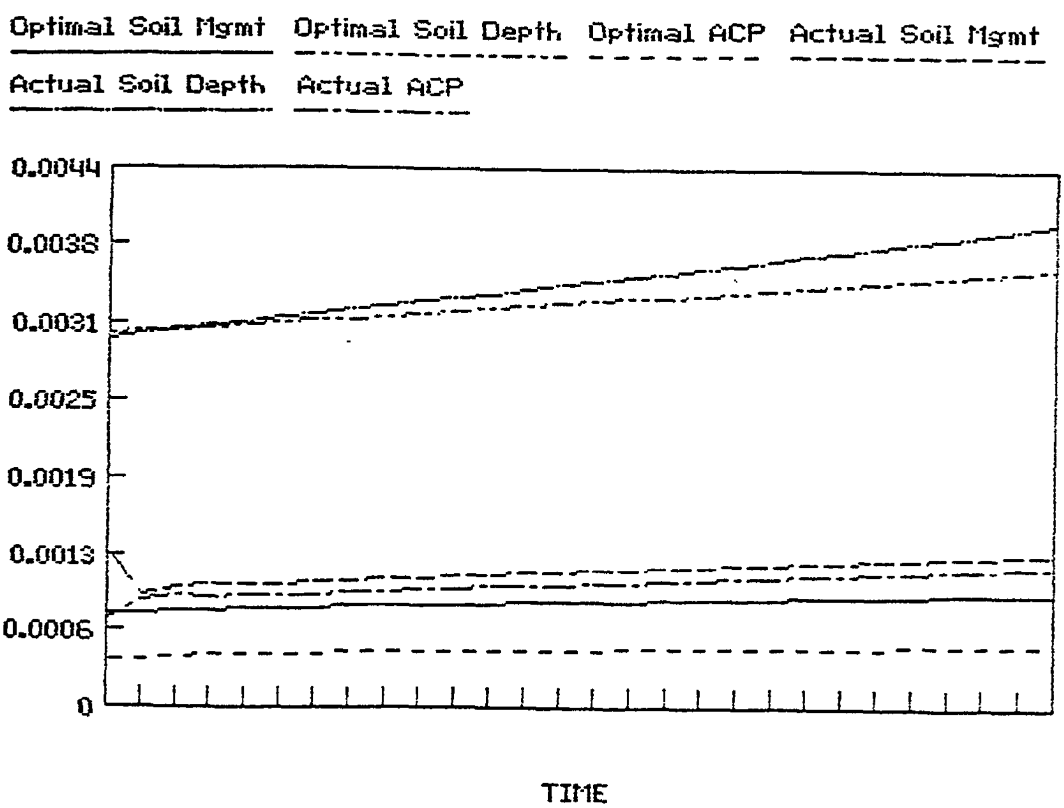


FIGURE 3: SHOCK TO ACP

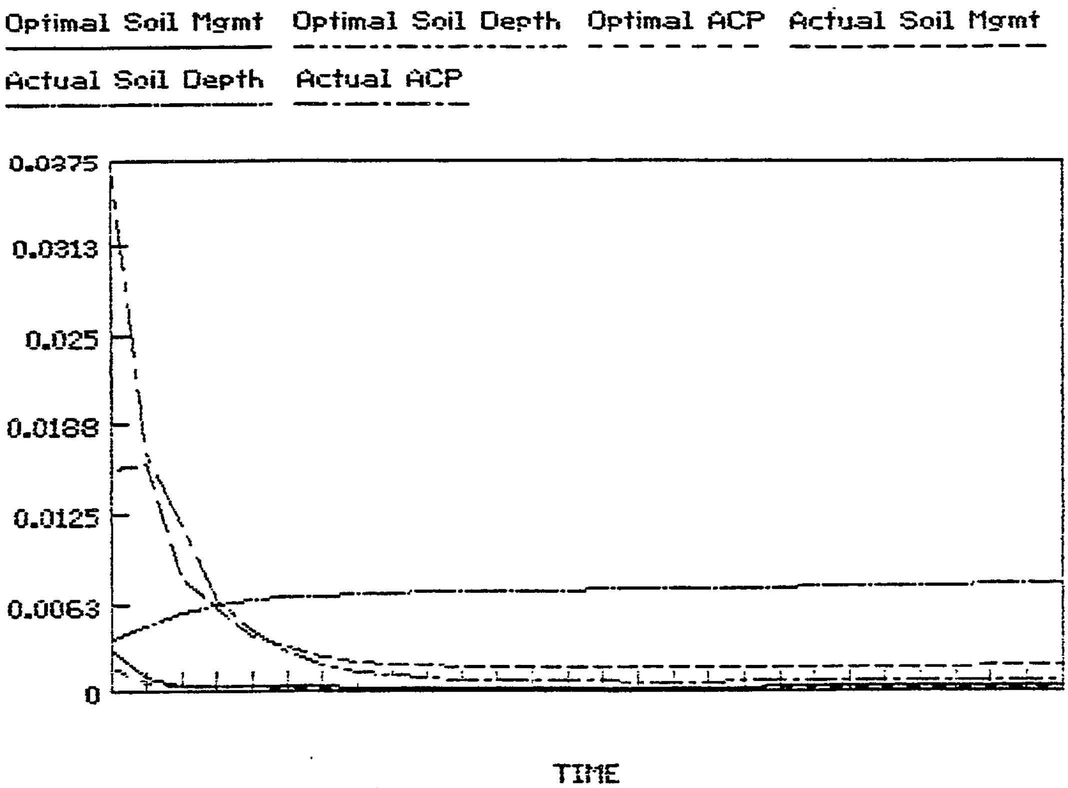


FIGURE 4: SOIL MANAGEMENT
SIMULATED VALUES

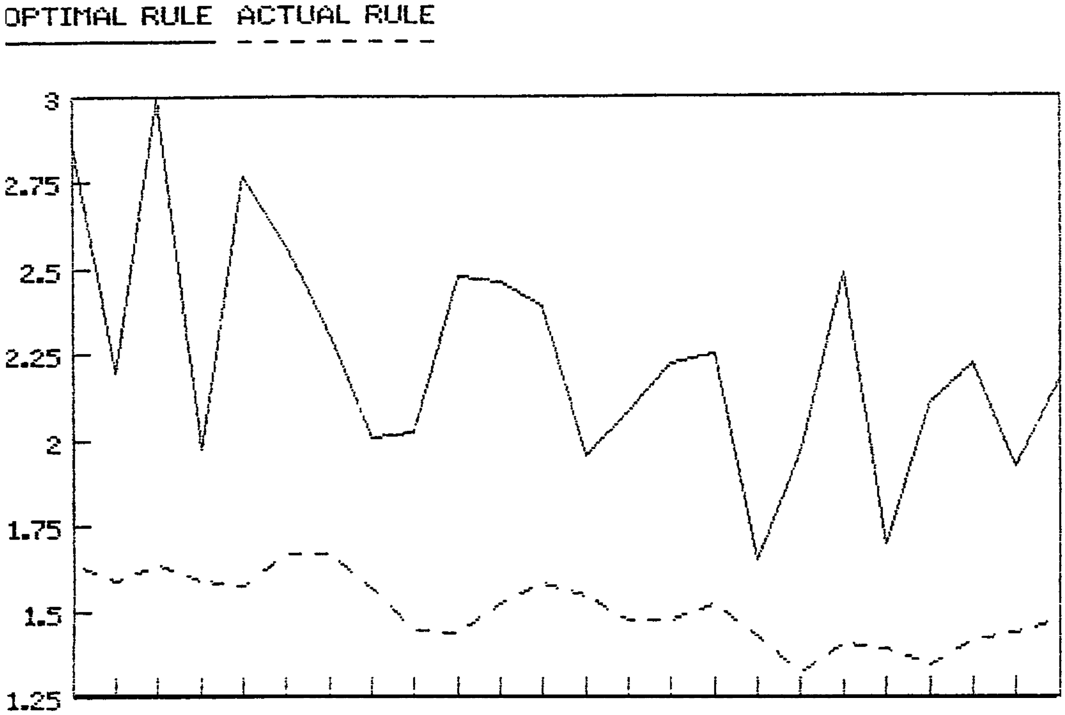


FIGURE 5: ACP
SIMULATED VALUES

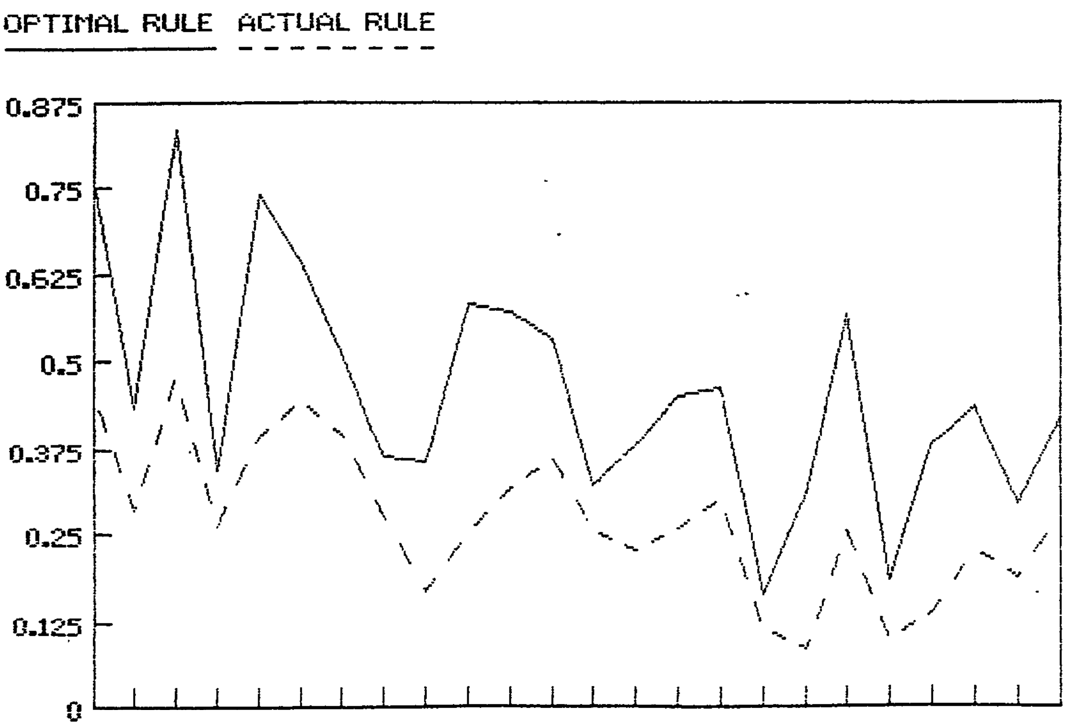


FIGURE 6: SOIL DEPTH
SIMULATED VALUES

OPTIMAL RULE ———— ACTUAL RULE - - - - - - - -

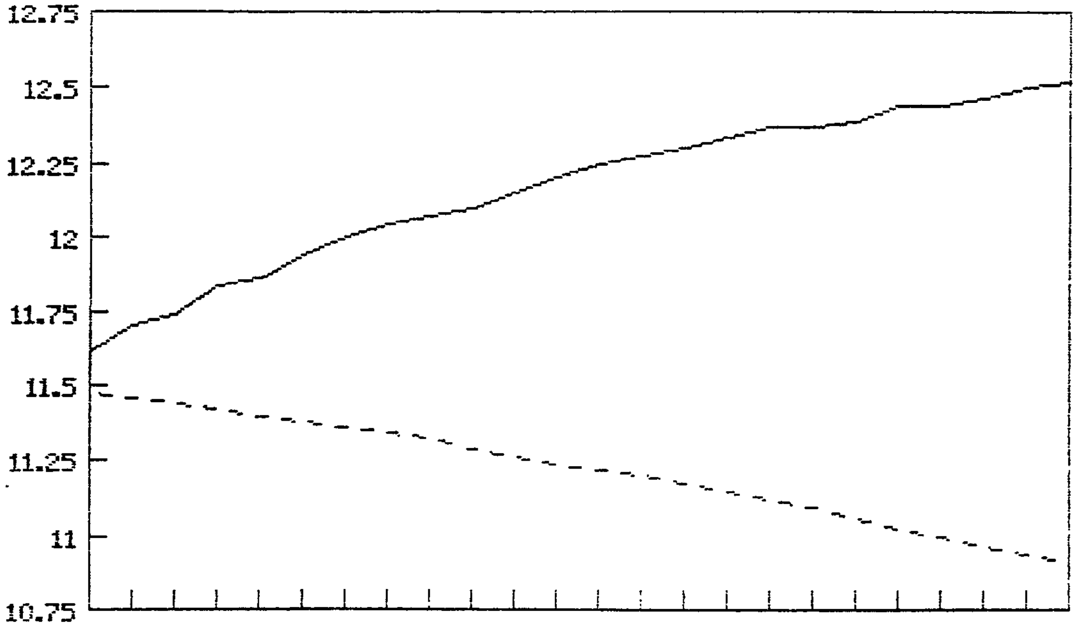
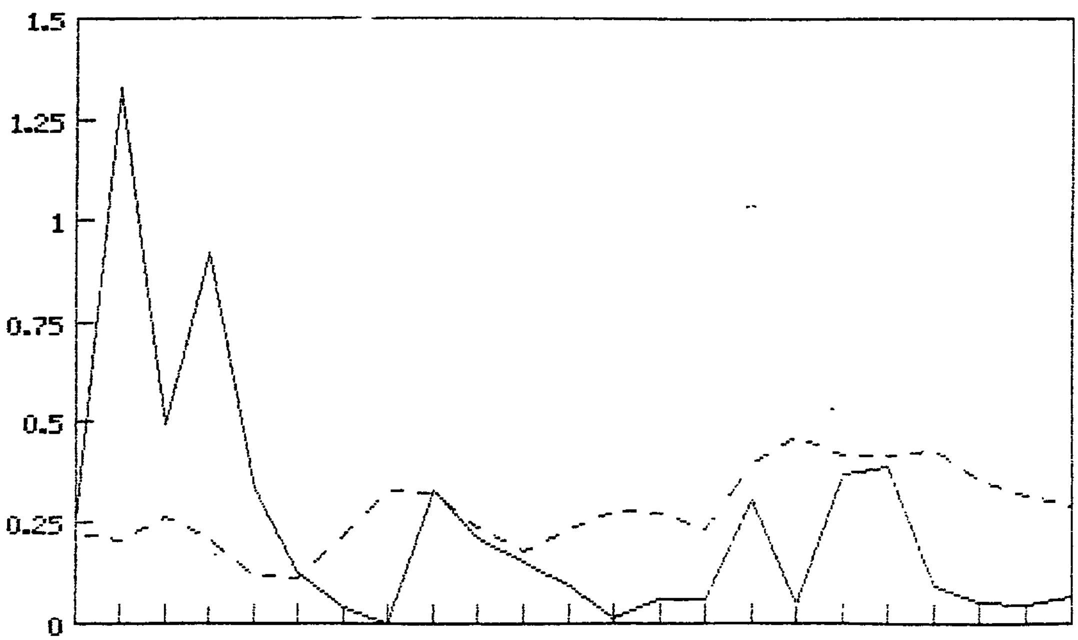


FIGURE 7: OBJECTIVE FUNCTION VALUE
SIMULATED VALUES

OPTIMAL RULE ———— ACTUAL RULE - - - - - - - -



1. The ACP is administered through the Agricultural Stabilization and Conservation Service (ASCS). The SCS provides mostly technical assistance, while the ACP is a program of subsidies and cost-sharing.

2. There is a large literature discussing optimal resource use rates. Specific applications to soil erosion are more limited. Burt (1981) and McConnell (1983) use dynamic models of farmer decisions to study soil erosion and its relationship to society's preferred level. Bromley (1982) discusses the difference between what society wants and what farmers find to be optimum. And Eleveld and Halcrow (1982) do an analysis based on Pareto optimality conditions. In a more recent analysis, Shortle and Miranowski (1987) focus on the offsight impacts of soil erosion, and the Social loss that accompanies it.

3. See Whiteman for a longer discussion of the difference between a time consistent rule and a precommitment one. Much of the application in this paper was inspired by his derivations in a generic model of optimal policy formulation. (Whiteman terms the time consistent policy the "mercurial" policy).

4. There are too many studies of this sort to cite all of them. Primary examples include Ervin and Ervin (1982), Napier and Forster (1982), and Saliba and Bromley (1984).

5. This description is based on the one in Moore, et al, (1979).

6. See Wischmeier and Smith (1978) for a discussion of soil tolerance levels. For our purposes it is necessary to note that soil erosion is of two primary types, rill and sheet, and is effected by the physical constraints (rainfall, soil type, field slope and shape) and management practices (essentially crop rotation and cultivation).

7. See Wischmeier and Smith (1978) or Heimlich and Bills (1984) for discussions of the USLE.

8. It is important to differentiate between T, the tons lost per acre, and "T". the tolerance level of erosion. The former is actual erosion, the latter is the normative value that soil scientists believe the soil can tolerate without suffering long-term productivity effects.

9. For notational convenience the function f(.,.,.) is unspecified here. In the first appendix a quadratic approximation is used to derive the expectational difference equation (7) which characterizes the farmer's choice of soil management through time. Rosenman (1986) includes an

estimation of a quadratic production function for different data.

10. This is actually the optimal precommitment rule if $M^*=S^*=0$. In the application the rule is derived far demeaned values, thus adhering to this condition, and then adjusted to level.

11. If h=0, then $d(m)d(m^{-1})=0$ and $m+m^{-1}=(1+d_1^2)/d_1$. Thus

$$F(z) = \{[zd(z)d(z^{-1})]/[d_1(1-mz)(1-m^{-1}z)]\}A(z).$$

Expanding the coefficient on A(z) shows it equals -1.

12. The derivation of equations (12) and (13) are given in Appendix A.

13. Notice that if $d_1=0$ equation (13) reduces to Whiteman's closed loop precommitment policy.

14. All of the calculations in this paper were carried out using the VAR Econometrics, Inc. software RATS. The equations were estimated by two-stage-least-squares using lagged soil depth, input prices and government subsidies. The path of relative prices was analyzed using OLS.

15. A description of the data is provided in Appendix C.

16. Let the optimization problem, equation (2) be

$$J = E\{M_t-M^*)^2 + h(S_t-S_{t-1})\}.$$

Then the first order condition to maximize J is its derivative with respect to S_t set equal to zero, taking as given equation

(7):

$$2h(S_t - S_{t-1}) + 2(M_t - M^*)(K_3/[d_1 + K_1 d_2]) = 0$$

where the term in the third set of parentheses is derived using the implicit function theorem. Rearranging gives the equation estimated in Table 5A.

17. The negative R^2 comes from an algorithm that computes this value using GLS estimates of the errors. It is also indicative of serial correlation in the errors. See Judge, et al, (1985, p.30 and p. 477).

18. The chi-square test was performed by regressing INPRI on a constant, and using the reported Box-Pierce Q-statistic to check for serial correlation. The reported statistic was 7.77, indicating no serial correlation.

19. Under the assumption that farmers are competitors in both the inputs and output markets, which allowed the specification with yield as a numeraire, this is not a surprising conclusion. If price shocks in the input and output markets are (uncorrelated) white noises, then their ratio should also follow a white noise around some central value. This is argument is strengthened when one realizes that Maine potatoes as a whole, the market used for these estimations, are often thought to be price takers against the potatoes grown in western markets.

20. It is important to realize that a negative shock on ACP in the actual system would have a strong, persistent and growing negative affect on soil depth, thus in times of budgetary crisis could have very deleterious outcomes on soil erosion.

The Effectiveness of EPA's Regulatory Enforcement: The Case of Industrial Effluent Standards

by

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Abstract

This study evaluates the effect of EPA water pollution standard enforcement on pollution in the pulp and paper industry. The original data set used consisted of a longitudinal data base of 77 pollution sources tracked on a quarterly basis from 1982:1 to 1985:1. EPA inspections have a statistically significant effect in the expected direction on pollution discharge levels, the probability of non-compliance, and the regularity of filing discharge monitoring reports. Although these effects are consistent with EPA's legislative mandate, they probably pass a benefit-cost test only for firms that make no capital expenditures and only modest operating expenditures following an inspection.

I. Introduction

In the almost two decades since the initial wave of social regulation, the academic literature has documented very few if any instances of a health, safety, or environmental regulation that have been an unqualified success. Indeed, in most cases the problem is even more fundamental. The typical analysis of government regulation has found that the regulation did not even fulfill its primary mission, much less pass some kind of more demanding benefit-cost test.

This absence of a well-documented case study of effective social regulation may be due in part to the particular set of regulations that has been selected for analysis. There is certainly no inherent economic reason why such regulations cannot play a productive role in our economy. In the case of environmental quality, for example, the externality problems being addressed are not handled well by markets, implying that government regulation has at least the potential for playing a beneficial role. However, this potential will fail to be realized if the regulations are ill-conceived, are not effectively enforced, or if the environmental problem has no feasible solution.

A brief review of past regulatory experiences may be instructive to put the Environmental Protection Agency's (EPA) water pollution control effort, which is the focus of this paper, in better perspective. It should be noted that most of these detailed evaluations have been done with respect to agencies other than EPA. Although there have been some treatments of EPA regulations in the academic literature,[1] as well as some assessments within the government,[2] none of these evaluations have been undertaken with the same degree of statistical rigor and detailed empirical analysis that has characterized analyses of health and safety regulations.

In large part this lack of attention stems from the greater difficulty in constructing an environmental data base.[3] The decentralized nature of polluting activity, some of which is clandestine, makes pollution levels more difficult to monitor than compliance with, for example, safety cap requirements. These difficulties posed for external evaluation may also generate monitoring problems for the agency's enforcement staff. An important issue to be addressed here is whether the prolonged process required for us to amass a sound environmental data base for the purpose of external analysis is a reflection of underlying intrinsic difficulties in the monitoring and enforcement of EPA regulations.

The past assessments of health and safety regulations have indicated that regulations have been ineffective in promoting

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[1] Robert W. Crandall, Controlling Industrial Pollution: The Economics and Politics of Clean Air (1983); Paul MacAvoy, The Regulation of Air Pollutant Emissions from Plants and Factories (1981); and B. Peter Pashigian, Environmental Regulation: Whose Self-Interests are being Protected?, 23 Econ. Inquiry 551 (1985), are excellent examples of such contributions.

[2] See, for example, U.S. General Accounting Office, Wastewater Dischargers Are Not Complying with EPA Pollution Control Permits (1983).

[3] See Robert W. Crandall, Controlling Industrial Pollution: The Economics and Politics of Clean Air (1983), for discussion of many of the problems confronted with respect to air pollution data.

their objectives for two general classes of reasons. The first of these is ineffectively designed regulatory policies. Thus, even though there is compliance with the regulatory requirements, little or no beneficial effect has been observed.

The seat belt requirements of the National Highway Traffic Safety Administration are one exhaustively studied instance of this type. Because many drivers do not use seat belts, and those that do may alter driving habits, the regulation has not produced the dramatic effect that the proponents of the regulation envisioned. Although some studies suggest that there has been no significant effect,[4] while others suggest a modest beneficial effect,[5] the overall implication is that there has not been a major effect of seat belts because the crucial behavioral link involving drivers was not considered by those designing the policy.

A similar effect has been observed with respect to the Consumer Product Safety Commission's safety requirements,[6] and more generally there is evidence that consumer product safety regulations are not sufficiently effective or extensive to have a substantial effect on product safety. Manufacturers have

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[4]For supporting data, see Sam Peltzman, The Effects of Auto Safety Regulation, 83 J. Pol. Econ. 677 (1975).

[5]Among the best of the optimistic assessments of seat belt regulations is that of Robert W. Crandall and John D. Graham, Automobile Safety Regulation and Offsetting Behavior: Some Empirical Estimates, 74 Amer. Econ. Rev. 328 (1984).

[6]See W. Kip Viscusi, Consumer Behavior and the Safety Effects of Product Safety Regulation, 18 J. Law & Econ. 527 (1985).

complied with the regulatory standards, but consumer safety has not been enhanced.

Much the same story is true in the pharmaceutical area. Pharmacists and doctors have complied with the U.S. prescription requirements for drugs, with only occasional notable violations. Nevertheless, in terms of the effect of prescriptions on health, no significant health effects of these requirements have been observed either for the United States or elsewhere in the world.[7]

The second reason for regulatory failure is the lack of enforcement. For example, the Occupational Safety and Health Administration (OSHA), has extensive regulatory requirements but traditionally has enforced them quite laxly. Indeed, the inspection rates are so low (less than one inspection per century per firm) and the penalties are so small (only $6 million annually) that there are few incentives for compliance. The result is that there has been at best a very modest effect on safety outcomes.[8]

The EPA water pollution regulations, which will be the focus of this study, represent an interesting departure from past patterns of regulatory failure. First, the nature of the regulations -- discharge limits -- is directly related to the

[7] For supporting data, see Sam Peltzman, The Health Effects of Mandatory Prescriptions, J. Law & Econ. (forthcoming).

[8] By the most extensive analysis is that in W. Kip Viscusi, The Impact of Occupational Safety and Health Regulation, 1973-1983, 17 Rand J. Econ. 567 (1986). Analysis of earlier periods of OSHA enforcement is provided in Ann Bartel and Lacy Thomas, Direct and Indirect Effects of OSHA Regulations, 28 J. Law & Econ. 1 (1985), and in Robert S. Smith The Impact of OSHA Inspections on Manufacturing Injury Rates, 14 J. Human Resources 145 (1979).

policy objective of controlling pollution, and there is no potential for offsetting behavioral responses. If the pollution standards are binding and if they are enforced, they should improve water quality. Second, the enforcement effort is so extensive that there should be an effect of enforcement on firms' compliance. In the pulp and paper industry, which we will analyze, EPA averages roughly one inspection annually. In addition, firms are required to file monthly discharge monitoring reports, providing one of the most thorough monitoring capabilities of any health, safety, or environmental agency. One of the potential weak links is that EPA officials cannot assess penalties for non-compliance directly. They can, however, seek the imposition of substantial penalties through court action.

In the subsequent sections, we will describe the nature of the EPA enforcement of water pollution regulations in the pulp and paper industry and the original data base we created for this study. Using information from EPA and industry sources, we constructed a longitudinal data base by firm that permits a detailed evaluation of the effects of EPA inspections, and their associated enforcement actions, on the behavior of pulp and paper plants. As the empirical results will indicate, we find diverse evidence of significant EPA effects on the polluting and reporting activities of firms in the pulp and paper industry.

II. Enforcement of Water Pollution Regulations in the Pulp and Paper Industry

In choosing to study the enforcement of environmental regulations by the U. S. Environmental Protection Agency and by state environmental agencies, we could have chosen several different media. Only for water pollution was it possible to find a relatively complete data base of pollution discharge measurements by source and a data base on enforcement actions at these same plants. The same informational base that permits us to provide a sound empirical analysis also assists EPA in its effort to monitor and enforce compliance. Overall, it is believed that more than 90 percent of all major water discharges are in compliance with EPA standards, as contrasted with estimated compliance rates as low as 20 percent for toxic and hazardous substance regulation.[9] Thus, one should be cautious in generalizing the record of EPA in the water pollution area to other types of pollution problems. The investigation reported here should be regarded as an examination of an important and representative component of one of EPA's most effective regulatory programs.

Since the data on inspections were much more complete than on other enforcement actions, such as administrative orders,

[9]For supporting data, see Cheryl Wasserman, Improving the Efficiency and Effectiveness of Compliance Monitoring and Enforcement of Environmental Policies, United States: A National Review, O.E.C.D. (1985).

notices of violations, warning letters, and telephone calls,[10] we focus on the relationship between plant inspections and water pollution discharge levels. This emphasis on inspections also accords with our a priori views regarding the role of different enforcement instruments since inspections are one of the most important components of any enforcement program and thus merit special attention.

To measure the relationship between inspections and subsequent compliance, we examine one industry, pulp and paper. This industry is the country's largest discharger of conventional pollutants, such as organic waste and sediment,[11] and it has a long history of water pollution enforcement efforts by various governmental agencies. There is no reason to believe that the effectiveness of inspections in the pulp and paper industry differs markedly from that in other industries regulated by EPA. Also, by concentrating on one industry, we avoid the problem of controlling for inter-industry differences in the stringency of regulations, differences in the nature of the pollution, and differences in the technologies for compliance.

EPA has traditionally focused on the control of Biological Oxygen Demand (BOD) because it is the most damaging conventional

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[10] One reason for the completeness of the data on inspections is that the EPA regional offices are not credited with conducting an inspection until it is coded into the central data base. See page iii in U.S. Environmental Protection Agency, Office of Water Enforcement, NPDES Inspection Manual (June, 1984).

[11] U.S. General Accounting Office, Water Pollution: Application of National Cleanup Standards to the Pulp and Paper Industry (March, 1987), page 8.

pollutant discharged by the pulp and paper industry.[12] Most inspections examine BOD levels in addition to other pollutants of interest for a given plant. Also, the technologies which control BOD discharges tend to reduce the levels of other pollutants, which means that the relationship between inspections and BOD discharge reductions ought to be similar to the relationship between inspections and discharge reductions for other pollutants.

The pulp and paper industry consists of hundreds of companies operating plants in 30 states within seven of the ten EPA regions in the country. The EPA Permit Compliance System (PCS) data base to be described below lists 418 separate sources of pollutant discharge. BOD, Total Suspended Solids (TSS), and the pH levels of discharges are the three main conventional pollutants controlled, although in recent years Congress has initiated new regulatory efforts to also control toxic pollutants.

If EPA water pollution standards were set in the same manner as seat belt regulations or OSHA standards, a description of the regulatory constraints would be straightforward. In the seat belt and OSHA cases, firms face well-defined requirements on the technology or work environment. All firms must comply with the same set of regulations, such as ensuring that punch presses have the specified guards. There has been little change over time in the nature of the standards, except that some new regulations

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[12]BOD is the standard measure of the organic pollutant content of water.

have been added. In contrast, EPA water pollution standards involve permissible pollution amounts that vary across firms and have. varied over time.

The 1972 Federal Water Pollution Control Act Amendments set the framework for regulation of industrial water pollution. The Act required that all sources discharging into the navigable waters of the country meet discharge standards based on the application of the "best practicable control technology" (BPT) by July 1, 1977, while complying with standards based on the "best available technology economically achievable " (BAT) by July 1, 1983.

In 1977 the Act was amended again, pushing back the 1983 deadline to July 1, 1984 and substituting a more complicated requirement. Conventional pollutants such as BOD.and TSS were to meet standards based on the adoption of the best conventional technology (BCT), while toxic pollutants were to meet standards based on the best available technology (BAT).

The final BPT and BAT standards for various subcategories of the pulp and paper industry were promulgated on three separate dates: May 9, 1974, May 29, 1974, and January 6, 1977. The final BCT standards were issued on December 17, 1986 and left the BPT standards for BOD control unchanged. The BPT standards generally set limitations on the quantities of BOD that a plant could discharge per pound of pulp or paper produced.[13] However,

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[13]For a formal description and analysis of the BPT rulemaking process, see Wesley A. Magat et al., Rules in the Making: A Statistical Analysis of Regulatory Agency Behavior (1986).

the allowable discharges of BOD from each source were derived by multiplying this effluent limitation by the number of pounds of pulp or paper produced per day at the plant. This latter number formed the basis of the National Pollutant Discharge Elimination System (NPDES) permit required of each discharger. Since our empirical study covers the period from the first quarter of 1982 through the first quarter of 1985, the NPDES permits restricting BOD discharge were based on the 1977 BPT standards.

EPA possesses the authority to issue the NPDES permits, but in the case of 37 states that have met specified federal criteria the authority has been delegated to the states. States certified to issue NPDES permits also assume responsibility for their enforcement, which means inspecting the plants and taking action against sources found to be out of compliance. For states not certified to run their own permit systems, EPA issues and enforces the permits.

An important aspect of the permit process should be emphasized. EPA and the states do not set uniform permit levels irrespective of the industry characteristics associated with the pollution source. Each standard is industry-specific and represents pollution levels that are potentially achievable with available technologies. While these permits need not pass a benefit-cost test, an effort is made to ensure that a partial *affordability* criterion has been met.

Each source must regularly measure its pollution discharge levels and report its actual discharges of each pollutant in its permit on a monthly basis through a Discharge Monitoring Report

(DMR). If a source is out of compliance with the effluent standards in its permit, it is also required to file a non-compliance report. The states and EPA regional offices send the DMRs to EPA, which enters them into the PCS data base to serve as a basis for tracking compliance. In addition, EPA requires that Quarterly Non-Compliance Reports (QNR) be filed by each state and region each quarter to identify sources out of compliance. In the empirical study that follows, we will use the reported BOD discharge levels in the DMRs to measure the effects of inspections on BOD discharge levels.

Because the sources are required to report their pollutant discharge levels on a monthly basis, the on-site inspections play a somewhat different role than inspections carried out by other regulatory agencies, such as an OSHA inspection of an industrial site. The latter inspections constitute the primary basis for the agency to check compliance with its regulations and to have a visible presence in the workplace. In contrast, EPA or state-run inspections of industrial water pollution sources create a similar visible presence, but they provide only a secondary source of information about compliance because the monthly DMRs address the compliance question directly. Some NPDES permit inspections do test whether the DMR discharge levels are reported accurately and honestly, and they provide an incentive for firms to submit DMRs more frequently.

The difference between EPA inspections and OSHA inspections has also been narrowing years. Although the Bureau of Labor Statistics does not release the mandated injury reports to OSHA for compliance purposes, OSHA now gathers this information through on-site records checks to target its inspections. This procedure represents a partial and more time-consuming variant of the DMR process. Firms with good injury records are exempt from OSHA inspections.

The EPA inspections directly address one or more of the following items: the existence of an up-to-date permit, the installation of the abatement equipment necessary for compliance with the permit, management plans and practices, the preparation and maintenance of records, the correct operation of the abatement equipment, and the conduct of sampling and sample analysis. As a recent EPA report to O.E.C.D. explains, "Despite widespread self-monitoring, inspections remain the backbone of agency compliance monitoring programs....inspections are the government's main tool for officially assessing compliance, and for assuring quality control and lending credibility to self-monitoring programs. The independent evaluation provided by a government inspection is the key".[14]

EPA carries out three main types of inspections -- compliance sampling inspections, compliance evaluation inspections, and performance audit inspections. Compliance sampling inspections require approximately 30 work days of time to complete and involve actual sampling of the effluent at the plant, as well as an examination of the company's record-keeping system, its testing procedures, and its treatment system. In contrast, the compliance evaluation inspections take only about 3

[14]Wasserman, supra, note 9, page III-7.

workdays to complete. They involve no sampling, but the inspectors do examine the company's treatment facilities, monitoring methods, and records. The performance audit inspections require about 12 days of time to complete and consist of the same practices used in the performance evaluation inspection, plus observation of the permittee going through all of the steps in the self-monitoring process from sample collection and flow measurement through laboratory analyses, data work-up, and reporting. In addition, the performance audit inspector may leave a.check sample for the permittee to analyze.

Based on the discharge reports in the DMRs and in the QNRs, as well as on the findings of inspections, EPA or the designated state agencies take enforcement actions against violators. Informal actions include telephone calls, warning letters, and notices of violation, as well as inspections. If these measures do not achieve the intended results, the control agencies can proceed with formal actions such as administrative orders, permit revision, formal listing of companies as ineligible for government contracts, grants, and loans, and finally, civil and criminal judicial responses.

Court action is a lengthy process involving the Justice Department that is only started as a last resort. Under Section 309(e) of the 1977 Clean Water Act, civil penalties could be awarded up to a level of $10,000 per day, while criminal penalties could range from $2,500 to $25,000 for the first violation and up to $50,000 for the second violation.[15] In addition, first violations could lead to imprisonment up to one year, with up to two years of imprisonment for the second violation. During the period from January 1, 1975 to July 1, 1985, EPA commenced only 64 judicial actions in the pulp and paper industry. Of these 42 cases resulted in fines and 4 were still pending at the end of the period. The fines varied from $1,500 to $750,000, with an average of $89,437. Because the regions lacked the incentives to regularly report enforcement actions other than inspections into the PCS data base, we concentrate our study on the effectiveness of the inspections on bringing firms into compliance with their permits. Thus, the inspections variable is intended to be a proxy for the overall enforcement effort associated with an inspection and all subsequent enforcement actions.

III. The Sample and the Variables

The Data Base

The PCS data base, which we utilize in our analysis, contains a file of inspections carried out on sources in every industry. The file for the pulp and paper industry shows only performance sampling and performance evaluation inspections for sources listing BOD discharge measurements, although the agency did carry out several performance audit inspections for lead

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[15] Under the 1987 Amendments to the Clean Water Act, the maximum civil penalty rose to $25,000 per day and the maximum criminal penalty increased to $50,000 for the first violation and $100,000 for the second violation.

pollution. For the period from the first quarter of 1982 through the first quarter of 1985 there were 276 inspections in the industry, of which 43 percent were compliance sampling and 57 percent were compliance evaluation.

The PCS data base lists 418 separate sources in the pulp and paper industry in its Inspections File, but only 77 of those sources submitted DMR measurements for BOD discharge into the Measurements File. The rest of the sources either did not submit DMRs including BOD measurements during the period under study, or their DMRs were not entered into the PCS data base, or they discharged pollutants other than BOD. Thus, we restrict our analysis to those 77 sources for which we have data on both inspections and BOD discharges. These 77 sources are located in six of the ten EPA regions, They are contained in SIC 26, further divided into five 4-digit SIC codes (2611, 2621, 2631, 2648, and 2661).

In this analysis we use calendar quarters as the unit of analysis. Only rarely was there more than one inspection for a given source in the same quarter. Despite the requirement that sources report DMRs every month to the state enforcement agency or EPA, which were then required to enter these data into the PCS data system, some DMR measurements are missing for the sources in our sample. In constructing the quarterly BOD measurements for our statistical analysis, we interpolated to fill in missing values and used averages of the BOD discharge levels within a quarter as the quarterly average BOD discharge levels.

Although the EPA analysts to whom we talked were confident that most of the discharge measurements in the DMRs were reported accurately, permittees do have several opportunities to cheat. They may choose not to report discharge measurements during months with unusually high discharge levels. This behavior would lead to some smoothing of the pattern of reported discharges, eliminating the top end of the distribution. More active attempts to mislead EPA include altering the contents of the sample being tested, falsely calibrating the test instruments, and recording false measurements in the DMRs.

Despite these possibilities for sending EPA misleading or false DMR discharge statistics, there are several incentives to report honest information in the DMF&. EPA follows the policy of attempting to inspect all major sources at least once a year. Compliance sampling inspections would detect whether most of the reported measurements were inconsistent with the measurements from the inspections, but they could not detect whether outliers were removed from the reports. Compliance evaluation inspections would detect the absence of the required abatement equipment, but would be less useful in evaluating whether the abatement systems were being operated correctly. Of course, the penalties for non-compliance and fraud in reporting also create incentives for truthful reporting of discharge measurements. The possibility of leaks to EPA by disgruntled employees makes this last incentive more compelling to firms considering manipulating their DMR data.

Taking into account the possibility that the DMR measurements may measure true compliance status with some error, it is still intructive to ascertain how well firms comply with the effluent regulations. Recently, the Environmental Protection Agency[16] issued a study of compliance by all the major pulp and paper mills (SIC 2611, 2621, 2631) in the eight Southeastern states comprising EPA Region IV over the period from the second quarter of fiscal year 1982 through the first quarter of fiscal year 1984. Eighty-two percent of the measurements fell within the permitted bounds. This compares with 75 percent of the measurements from the pulp and paper firms in our sample being in compliance. EPA further defines significant non-compliance for BOD as violations of the monthly average permit limits for any two months in a six-month period that exceed the limit by 40 percent, or violations of the monthly average limits for any four months in a six month period. Using this definition, 94 percent of the measurements indicated discharge levels not in significant non-compliance. The study also showed that four out of the 56 mills created most of the instances of significant non-compliance.

Sample Characteristics

Table 1 summarizes the means and standard deviations for the sample of the variables used in our analysis. The sample is a pooled time series and cross section of 77 plants followed on a quarterly basis from 1982:1 to 1985:1. The first two variables represent the pollution outcome measures that will be of primary interest as dependent variables in different equations. The

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[16] U.S. Environmental Protection Agency, Study of Pulp and Paper Industry in Region IV (1986).

TABLE 1: Means and Standard Deviations of variables Describing 77 Plants in Sample (1982.1 - 1985.1)

ariable	Mean	Standard Deviation
QAVG (pounds/day)	5758.288	8919.173
VIO (1 = out of compliance)	0.252	0.434
QTR1 (1 = inspection 1 quarter prior to measurement)	0.248	0.432
QTR2	0.273	0.446
QTR3	0.273	0.446
QTR4	0.281	0.450
QTR5	0.300	0.458
QTR6	0.295	0.456
:GN1 (1 = source located in Region 1)	0.095	0.293
:GN2	0.002	0.039
:GN3	0.064	0.244
:GN4	0.154	0.361
:GN5	0.039	0.193
.GN6	0.435	0.496
GN7	0.000	0.000
GN8	0.000	0.000
GN9	0.000	0.000
GN10	0.213	0.410
C11 (1 = pulp mill)	0.241	0.428

TABLE 1
(cont.)

Variable	Mean	Standard Deviation
SIC21 (1 = paper mill excl. building)	0.432	0.496
SIC31 (1 = paperboard mill)	0.253	0.435
SIC47 (1 = sanitary paper products)	0.012	0.111
IC48 (1 = stationary products)	0.014	0.117
IC49 (1 = converted paper)	0.000	0.000
IC61 (1 = building paper or paper board mill)	0.048	0.214
ONS (daily output rate)	794.156	587.083

variable MQAVG is a continuous measure of the extent of pollution. It measures the number of pounds of BOD discharged per day, where this amount is averaged over the quarter. Although the amount of pollution is a variable of substantial economic interest, it is not the sole variable of concern. Different firms may have different permitted pollution levels so that, for example, a large plant may be in compliance with a high BOD level whereas a small plant may be in violation of its permit even though its discharge is less. Analyzing the effect of inspections on total discharges is, however, one of the most important ways of assessing the benefits of EPA's regulatory enforcement.

The second pollution variable, MVIO, is a discrete 0-1 variable that takes on a value of 1 if the pollution source is in non-compliance with its BOD standard in any of its monthly measurements in that quarter. This variable best captures whether the firm's performance is in compliance with its water pollution permit, but it does not reflect the extent of non-compliance. Unfortunately, it is not possible to construct a reliable measure pertaining to the amount pollution in excess of the permitted amount since data pertaining to the level specified in the permit are not available from the PCS data base. Instead, we will be restricted to MQAVG and MVI0 rather than a hybrid of a continuous pollution measure and discrete compliance measure.

The next set of variables is a series of 0-1 dummy variables pertaining to whether the firm was inspected in a particular quarter. The variable IQTRJ is of the general form in which it takes on a value of 1 if the pollution source received an inspection J quarters previous to the pollution measurement in the current quarter, where J takes on a value from 1 to 6. It is quite striking that the rate of inspection is quite high, on the order of 25 to 30 percent of the quarters.

This relatively high inspection rate distinguishes the EPA enforcement effort from that of OSHA. Not only does EPA receive regular discharge monitoring reports from firms, but it also undertakes water pollution inspections at a rate of about one inspection annually per major pollution source. OSHA not only has no automatic data feedback mechanism, but it also has a much more sporadic inspections effort. In OSHA's early years, some analysts equated OSHA's inspection frequency to other rare events such as the annual chance of seeing Halley's Comet. At present, the OSHA inspection rate is much lower than this amount -- on the order of 1/200 for each firm in any year.[17] The intensity of EPA inspections consequently dwarfs that of OSHA inspections so that there is no reason to believe that the lack of efficacy of OSHA's minimal enforcement operation has any adverse implications for EPA's chances of success.

The variables of the form REGNJ are 0-1 dummy variables for the EPA region J in which the plant is located. These variables will be utilized to ascertain whether there are any important regional differences in pollution patterns. It should be noted

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[17]See page 259 of W. Kip Viscusi, Reforming OSHA Regulation of Workplace Risks, in Regulatory Reform: What Actually Happened (L. Weiss and M. Klass eds. 1986).

that there are no pulp and paper mills located in three of the EPA regions (7, 8, and 9).

The next set of six variables are of the form SICJK, which represents a dummy variable for the plant's four digit SIC industry code 26JK, where JK takes on the values 11, 21, 31, 47, 48, 49, and 61. Although all firms are in the pulp and paper industry, it was desirable to also include refined industry group dummy variables that reflect the firm's specific operations and technology. For example, pulp mills (SIC 2641) have different operations than converted paper plants (SIC 2649).

TONS is the final variable listed. It measures the number of tons of pulp and paper produced daily at the plant. Unlike the other variables in the data set, this variable was not included in the PCS data base. We matched each firm to a capacity measure using data provided in a published industry directory.[18]

IV. The Effect of Inspections on Pollution

The major purpose of this paper is to empirically measure the effects of inspections, along with their associated enforcement actions, on the behavior of firms in the pulp and paper industry. We will concentrate on an econometric approach which relates the conduct of an inspection in a given quarter to two measures of the firm's BOD abatement effort: (i.) its absolute rate of effluent discharge (MQAVG); and (ii) whether its

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[18]See Lockwood's Directory of the Paper & Allied Trades, (1983 ed.).

discharge rate falls below its permitted level (MVIO). As well, we also examine the effect of plant inspections on reducing the incidence of non-reporting of DMR data. To the extent that firms purposely refrain from reporting discharge levels during periods of non-compliance, the first two measures of the impact of inspections would be biased towards less impact than actually occurred. This third measure allows us to determine whether inspections improve the completeness of EPA's discharge monitoring system, which presumably leads to more discovery of non-compliance and, through subsequent enforcement efforts, further reductions in pollutant discharge levels.

Empirical Framework for Measuring Abatement Effects

The underlying economic framework is straightforward, as pollution levels are governed by a capital investment process relating to the pollution control technology, as well as by the efficiency levels at which the abatement equipment is operated. The role of EPA inspections is to raise the expected cost of non-compliance, boosting the incentives for pollution reduction and compliance with the permit. Since the underlying theoretical basis is straightforward, we will proceed directly to the estimating equations.[19]

The equations to be estimated will be of the same general form whether the pollution variable is MQAVG or MVI0. To

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[19]The model implicit here is articulated more fully for the analogous job safety case in W. Kip Viscusi, The Impact of Occupational Safety and Health Regulation, 10 Bell J. Econ. 117 (1979). More generally, see Richard Posner, Economic Analysis of Law, Third Edition (1986).

illustrate this general form, let $POLLUTION_{it}$ be the value of the pollution variable MQAVG or MVIO for pollution source i in period t. Some additional notation is needed before we can write down the equation to be estimated. The variable $IQTRJ_{it}$ is the 0-1 inspection variable for whether pollution source i was inspected in period t-J, $TONS_i$ is source i's capacity measure, SIC_i is a vector of four-digit SIC code dummy variables for pollution source i, $REGN_i$ is a vector of dummy variable for the EPA regions for source i, and $QUARTER_t$ is a vector of dummy variable for the quarters. The resulting estimating equation is of the form

$$POLLUTION_{it} = \alpha + \beta_1 \; POLLUTION_{it-4} + \sum_{k=1}^{n} \gamma_k \; IQTR_{t-k}$$
$$+ \beta_2 TONS_i + \beta_3 SIC_i + \beta_4 REGN_i$$
$$+ \beta_5 QUARTER_t + v_{it},$$

where v_{it} is a random error term, In the case of the continuous pollution measure, MQAVG, ordinary least squares is the appropriate estimator, whereas for the discrete compliance variable, MVIO, a logistic estimation procedure is employed. With some modifications, this equation is in the same general spirit as similar equations estimated for safety regulations.[20]

The first variable included is the lagged dependent variable, with the noteworthy distinction that the lag is 4 quarters rather than 1. The variable $POLLUTION_{it-4}$ is a proxy for the firm's stock of capital related to pollution control and for the general character of its abatement technology. Firms

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[20]The equation bears closest similarity to those in Viscusi, supra, note 8.

with high levels of pollution in the past are likely to continue to have high levels in the future because the nature of their control technology makes it costly to achieve pollution reductions. A four-quarter lag is utilized rather than a single quarter lag to capture the seasonality that often plays an important role in a firm's operations. The products produced, stream flow conditions, and the pollution permit amount may vary by season.

The lagged dependent variable serves an additional role with respect to regression-to-the-mean effects. It is possible that firms with an abnormally high pollution level in period t due to stochastic factors will be inspected in period t+1 and improve their performance compared with period t, wholly apart from any true inspection effect. Because the lagged values captures pollution levels, or compliance status, 4 quarters earlier, however, they are less susceptible to leading to inspection variable results that simply capture regression-to-the mean effects.

The next set of variables is a distributed lag on past EPA inspections. Evidence for OSHA suggests that there is generally a lag before firms can make the required capital investments to alter their performance level.[21]

Even if compliance only entails changes in operating procedures following an inspection, an effect may not be apparent until the next quarter. Consider a situation in which the firm files its DMR data for the first month in the quarter in the

[21] See Viscusi, supra, note 8.

middle of the second month of the quarter. Even if EPA undertakes an inspection immediately, which is not usually the case, the sampling will not be completed until the middle of the final month of the quarter. Thus, under this best case scenario only half a month, or one-sixth of the pollution discharges for the quarter will be affected by the inspection. Because of the time lags before EPA receives the DMR data, the time needed before EPA can schedule an inspector to make a plant visit, the rather lengthy inspection process, and the time needed before EPA makes its report to the firm and the firm can take action upon it, no contemporaneous effect is expected.

Before requiring that any inspection effect enter with a lag, we tested empirically for whether the inspection variable led to a contemporaneous negative effect on pollution. Rather than observing a negative effect, there was a strong and statistically significant positive influence, which is consistent with the reverse causality hypothesis. We explored the causality issue in greater detail. Based on a Hausman[22] specification test, we were able to reject the hypothesis that the IQTRit variable is exogenous. Attempts to replace $IQTR_{it}$ (t=0) by an instrumental variable estimator also led to positive coefficients, suggesting that the primary relationship between the two variables is through high current levels of pollution leading to EPA inspections rather than inspections causing immediate reductions in pollution discharge levels. These

[22] Jerry Hausman, Specification Tests in Econometrics, 46 Econometrica 1251 (1978).

results allow us to use only lagged inspection variables without losing any of the effects of the inspections on compliance, or creating a bias in our estimated coefficients.

The next variable, $TONS_i$, pertains to the capacity of the firm. Other things being equal, firms with larger capacity should produce more pollution MQAVG, but need not necessarily be more likely to be in or out of compliance with EPA standards. There may be economies of scale with respect to pollution control which would tend to make large firms less likely to be out of compliance. Similarly, the TONS variable may pick up factors related to the vintage of the technology to the extent that larger plants are newer and have less polluting technologies. If these large plants are considerably more efficient in controlling pollution, the absolute levels of pollution may be lower than smaller and more outmoded facilities.

Technological factors of this type will also be captured in the SIC code dummy variables, implying that differences in technologies and standards across parts of the pulp and paper industry will be taken into account. The regional dummy variables REGNJ also capture firm characteristics to some extent since plants in some regions tend to be older than those in other regions. These regional variables also reflect regional differences in standard setting and the nature of enforcement. These differences may be considerable due to the prominent role that the states have in the enforcement process.

The final set of variables is a series of 17 quarterly dummy variables for all but one of the quarters represented. This formulation was chosen over a simple time trend variable because of its greater flexibility. Not only do the $\mathbf{QUARTER}_t$ variables capture any possible uniform time trend, but they also capture other quarter-specific effects such as any seasonal and cyclical fluctuations production levels and water flows. Although some quarterly dummy variables were statistically significant, these coefficients are not reported since there was no apparent pattern evident in the results. We regressed MQAVG against both a continuous TIME variable and its square, but found no significant relationships.

Regression Results

Table 2 reports the ordinary least squares (OLS) results for the continuous pollution measure, MQAVG, and Table 3 reports the maximum likelihood estimates for the non-compliance variable, MVIO. Because of the close similarity of the findings, we will discuss each of the variables in turn for both of the tables.

The four-quarter lagged pollution variable has the expected strong positive effect on the current pollution status, which suggests that past pollution levels predict current discharge levels accurately because of the slowness of the capital expenditures process needed to transform their status. Since the MVIO variable has been altered by the logistic transformation, the results for the continuous pollution measure, MQAVG, can be interpreted more readily. It is quite striking that the weight placed on the four-quarter lagged pollution value is in excess of 0.98 in each of the four equations. Thus, there is almost complete replication of the pollution experience across time.

TABLE 2: Regression Equations for MQAVG (Quarterly Average BOD Discharge Levels in pounds/day)[a]

ndependent ariables	Coefficents (Std. Errors) 1[b]	2	3	4
NTERCEPT	-434.029	-460.454	-494.034	-213.905
	(1683.935)	(1650.046)	(1592.309)	(1557.062)
VIOT4	0.983	0.983	0.983	0.982
	(0.021)	(0.021)	(0.020)	(0.020)
QTR1	-1174.689	-1059.423	-1064.031	-1148.911
	(517.225)	(511.525)	(497.787)	(487.430)
QTR2	575.256	381.999	398.665	---
	(495.099)	(481.687)	(469.908)	---
QTR3	-198.047	-155.912	---	---
	(467.133)	(463.305)	---	---
QTR4	77.479	59.709	---	---
	(468.403)	(450.159)	---	---
QTR5	374.924	---	---	---
	(468.248)	---	---	---
QTR6	-584.136	---	---	---
	(440.411)	---	---	---
QTR1x	---	---	---	---
MVIOT1	---	---	---	---
QTR2x	---	---	---	---
MVIOT2	---	---	---	---
QTR3x	---	---	---	---
MVIOT3	---	---	---	---
QTR4x	---	---	---	---
MVIO4	---	---	---	---
QTR5x	---	---	---	---
MVIO5	---	---	---	---
QTR6x	---	---	---	---
MVI06	---	---	---	---
NS	0.322	0.320	0.320	0.329
	(0.438)	(0.439)	(0.437)	(0.437)
C11	414.177	382.955	410.222	310.442
	(1408.440)	(1408.522)	(1394.943)	(1389.408)
C21	262.356	219.433	252.081	112.177
	(1418.355)	(1414.941)	(1393.285)	(1382.926)
C31	-205.950	-278.427	-253.484	-365.172
	(1426.645)	(1424.948)	(1410.265)	(1403.533)
C47	---	---	---	---
	---	---	---	---
C48	31.976	-41.814	17.162	-241.752
	(2806.433)	(2789.052)	(2719.955)	(2701.675)
C49	---	---	---	---
	---	---	---	---
GN1	248.482	225.870	213.567	322.009
	(909.025)	(895.892)	(862.661)	(852.791)

TABLE 2
(cont.)

ndependent ariables	Coefficents (Std. Errors) 1[b]	2	3	4
EGN2	---	---	---	---
	---	---	---	---
EGN3	-499.882	-500.628	-533.588	-360.471
	(1864.535)	(1823.241)	(1764.428)	(1751.873)
EGN4	230.897	219.572	204.147	310.894
	(890.368)	(846.406)	(807.680)	(797.493)
EGN5	59.067	107.966	115.888	147.361
	(1298.116)	(1299.413)	(1295.674	(1294.613)
EGN6	276.987	269.784	265.636	307.939
	(625.214)	(611.374)	(597.714)	(595.387)
EGN7	---	---	---	---
	---	---	---	---
EGN8	---	---	---	---
	---	---	---	---
EGN9	---	---	---	---
	---	---	---	---
lj. R^2	0.903	0.903	0.904	0.904
	373	373	373	373

Each equation also included 17 quarterly dummy variables.

Equation 1 uses a second-order polynomial distributed lag formulation IQTR1-IQTR6.

TABLE 3: Maximum Likelihood
Equations for MVIO (Non-Compliance with
BOD Standards)[a]

ndependent Variables	Coefficients (Asymptotic Std. Errors) 1	2	3	4
NTERCEPT	-7.872	-7.648	-7.991	-8.012
	(23.008)	(22.884)	(22.884)	(23.113)
VIOT4	2.650	2.637	2.640	2.641
	(0.362)	(0.359)	(0.356)	(0.356)
QTR1	-1.12	-1.019	-0.920	-0.914
	(0.442)	(0.429)	(0.418)	(0.413)
QTR2	-0.063	-0.134	-0.037	---
	(0.421)	(0.411)	(0.396)	---
QTR3	-0.606	-0.644	---	---
	(0.398)	(0.396)	---	---
QTR4	-0.030	-0.141	---	---
	(0.387)	(0.369)	---	---
QTR5	0.448	---	---	---
	(0.389)	---	---	---
QTR6	0.071	---	---	---
	(0.360)	---	---	---
QTR1x	---	---	---	---
MVIOT1	---	---	---	---
QTR2x	---	---	---	---
MVIOT2	---	---	---	---
QTR3x	---	---	---	---
MVIOT3	---	---	---	---
QTR4x	---	---	---	---
MVIO4	---	---	---	---
QTR5x	---	---	---	---
MVIO5	---	---	---	---
QTR6x	---	---	---	---
MVI06	---	---	---	---
NS	-5.07×10^{-4}	4.971×10^{-4}	-5.127×10^{-4}	-5.124×10^{-4}
	(4×10^{-4})	(3.956×10^{-4})	(3.913×10^{-4})	(3.91×10^{-4})
C11	6.321	6.263	6.396	6.405
	(22.998)	(22.875)	(23.108)	(23.106)
C21	5.800	5.754	5.958	5.968
	(22.999)	(22.876)	(23.109)	(23.107)
C31	5.352	5.306	5.423	5.431
	(23.00)	(22.877)	(23.110)	(23.109)
C47	---	---	---	---
	---	---	---	---
C48	2.506	2.404	3.064	3.084
	(23.077)	(22.951)	(23.178)	(23.175)
C49	---	---	---	---
	---	---	---	---

TABLE 3
(cont.)

ependent riables	Coefficients (Asymptotic Std. Errors) 1	2	3	4
N1	1.709	1.791	1.540	1.531
	(0.746)	(0.736)	(0.690)	(0.683)
N2	---	---	---	---
	---	---	---	---
3	2.188	2.474	2.033	2.015
	(1.481)	(1.412)	(1.336)	(1.319)
N4	1.098	1.316	1.101	1.094
	(0.685)	(0.655)	(0.621)	(0.615)
N5	1.835	1.868	1.951	1.950
	(0.888)	(0.889)	(0.877)	(0.876)
N6	-0.531	-0.404	-0.530	-0.535
	(0.524)	(0.505)	(0.482)	(0.480)
N7	---	---	---	---
	---	---	---	---
N8	---	---	---	---
	---	---	---	---
N9	---	---	---	---
	---	---	---	---
Log L	281.30	282.64	285.35	285.39
	374	374	374	374

ach equation also included 17 quarterly dummy variables.

All else being equal (in particular, controlling for inspections), past pollution performance is close to a perfect predictor of current pollution levels.

The next set of variables pertains to the set of lagged inspection variables. Consider the continuous discharge measurements in Table 2. In equation 1 there is a second-order polynomial distributed lag over inspection variables for the preceding six quarters, equation 2 is a free-form lag over four quarters, equation 3 is a free-form lag over two quarters, and equation 4 includes only a single lagged value. The pattern is strikingly similar in all four equations. There is a consistently significant and substantial influence of IQTR on reducing discharge levels that occurs with a one quarter lag. Lagged values of more than a quarter are not consequential. The discrete compliance status equations in Table 3 convey the same influence of inspections, that is, they cause significant reductions in the rate of non-compliance in the subsequent quarter.[23]

The magnitude of the inspection effect is substantial. Consider equation 4 in Table 2. Each inspection reduces the value of MQAVG by 1149 pounds per day, which represents about a 20 percent reduction in the mean value of BOD discharges. Since

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[23]We are uncertain why most of the effect of the inspections appears to occur in the quarter following the inspection. More detailed case studies of responses of individual plants to specific inspections would help explain this pattern of responses. Our results suggest that inspections tend to induce reduced discharge levels and enhanced compliance through immediate attention to better plant operation and maintenance, rather than longer term capital investments.

the coefficients of subsequent IQTR variables are never significantly positive, there is no evidence of a significant post-inspection rebound in pollution discharge levels. These results imply that a permanent improvement in discharge levels takes place as a consequence of the inspection and all associated enforcement actions. Further, the 1149 pounds/day reduction in BOD in period t is reflected in an approximately equal reduction four quarters hence because the coefficient of MQAVG4 is 0.982. Thus, inspections substantially reduce BOD discharges after about one quarter, and they have a permanent effect on reducing the firm's future pollution levels.[24]

The compliance status results from Table 3 also indicate a large effect of the inspections, and their associated enforcement actions, on non-compliance rates. The coefficients of IQTR1 in equations 1 through 4 average -1.0, implying that had the source not been inspected its odds of being in non-compliance would have been about double. Since most plants in the sample were inspected about once a year and the average rate of non-compliance is 25 percent, the coefficients from the table suggest that without an inspection this non-compliance rate would have been 48 percent.

Finally, the TONS measure has the expected sign in,each case, as firms with larger capacity have higher total levels of

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[24]A recent paper by Jonathan S. Feinstein (Detection-Controlled Inference, M.I.T. Department of Economics, 1986) provides an econometric argument for why the coefficients of the inspection variables would be biased downwards if detection of non-compliance through the non-submittal of DMR data, our results about the impact of inspections provide a lower bound on their true magnitude.

pollution and lower chances of being out of compliance. Neither effect is statistically significant, however. Similarly, the SIC and regional dummy variables fail to yield any statistically significant effects.

Effects on the Incidence of DMR Non-Reporting

While our econometric results in the beginning of this section clearly point to the conclusion that plant inspections cause firms to both reduce their pollutant discharge levels and come more closely into compliance with their discharge permits, inspections do serve other purposes as well. One of these is to induce firms to report more regularly their discharge levels to EPA or the designated state enforcement agency. We now examine whether inspections tended to reduce the incidence of DMR non-reporting.

Table 4 suggests that there is such a reporting effect. The first line in the table measures the difference between number of months that DMR data was submitted in the four months prior to an inspection and number of months with DMR data in the four months immediately following the inspection, averaged across all inspections in one of two periods, May, 1977 - November, 1984 and May, 1982 - November, 1984. The second line reports the analogous. differences for a six-month period before and after the inspections, while the third line uses of 12-month period for DMR data. All six mean differences are negative and more than two standard errors away from zero, indicating high levels of

TABLE 4: Mean Difference Between the Number of DMR Reports Before an Inspection and the Number of DMR Reports After an Inspection

No. of Months of Possible DMR Data Prior To and After Inspection	Mean Difference Averaged Across All Inspections in Period (Std. error of mean)
1) Four months	
a) May, 1977-Nov., 1984	-0.386 (0.060)
b) May, 1982-Nov., 1984	-0.425 (0.108)
2) Six months	
a) July, 1977-Sept., 1984	-0.714 (0.090)
b) July, 1982-Sept., 1984	-0.868 (0.173)
3) Twelve months	
a) Jan., 1978-Mar., 1984	-2.107 (0.196)
b) Jan., 1983-Mar., 1984	-1.693 (0.477)

statistical significance. Thus, the completeness DMR reporting is clearly higher after inspections.

We must add one note of caution in interpreting these statistics because the mean differences are not adjusted for the trend of increased reporting of DMR data. Still, this trend could not explain much of this difference. To be conservative, consider the first line of the table reporting four months of DMR data where the trend ought to be least important. For both the long and short periods the mean difference averages about -0.10 reports per months, which implies that inspections cause one additional month of DMR data to be reported out of every 10 months. If the underlying trend of increased reporting accounted for, say, half of this difference (that is -0.051, then less than 20 months would have to pass before no more non-reporting of DMR data would occur. Since the period from May, 1977 to November, 1984 (line a) contains 84 months, the underlying trend must be negligible relative to the rates of increased reporting of DMR data implied by the mean differences in Table 4.

Thus, inspections do tend to cause increased reporting of DMR data, which in turn allows EPA to monitor more accurately, and therefore enforce, its water pollution standards.

V. Exploratory Benefit-Cost Analyses

One might conclude that EPA inspections are successful because all three of our measures of firms' responses to inspections show significant effects. From a social welfare perspective, however, this question requires valuing the benefits of the effluent reductions induced by an inspection and comparing these benefits to the full costs of each inspection. In what follows, we provide a preliminary exploration of the components of such a benefit-cost analysis. Unfortunately, the existing estimates of the benefits per ton of BOD eliminated per year are only approximate, and we could find no estimates of the compliance costs due to an inspection. As a result, this exercise is highly imprecise. Nevertheless, it does provide some perspective on the welfare consequences of the EPA inspection program for industrial water pollution.

Vaughan and Russell (p. 161)[25] have estimated the national benefits from the improvements in freshwater quality due to the BPT standards at $683 million (in $1980). While this estimate includes both the out-of-pocket expenses and the opportunity costs of the time of fishermen, it does not include the aesthetic benefits of fishing on cleaner waters, nor other benefits such as those from swimming and boating. Development Planning and Resource Associates[26] estimated that the BPT standards would reduce BOD discharges by 3,390,233 tons per year, which together with the previous estimate implies an average value of benefits per ton of BOD removed due to the BPT standards of $201.46.

Using equation (4) in Table 2, each inspection will tend to cause a reduction in BOD discharges of 1,148 pounds per day, or

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[25] William J. Vaughan & Clifford S. Russell, Freshwater Recreational Fishing: The National Benefits of Water Pollution Control (1982).

[26] Development Planning and Resource Associates, Inc., National Benefits of Achieving the 1977, 1983, and 1985 Water Quality Goals (1976).

209.51 tons per year. Given the previous benefits estimate of $201.46 per ton, this implies that an average inspection produces $42,208 of benefits every year.[27]

Given the 0.982 coefficient of the MQAVG variable lagged four quarters in equations (4) in Table 2, the effectiveness of an inspection in maintaining lower effluent discharge levels decays at a negligible rate. Accepting the linear form of the equation and rounding this coefficient to 1.0, the equation implies that any BOD reductions from an inspection remain in force for years after the inspection. Thus, we can approximate the annualized benefits per inspection at about $42,208.

Given the mix of inspections in our sample of 43% compliance sampling inspections (requiring 30 days) and compliance 57% evaluation inspections (requiring 3 days), an average inspection required 14.6 days. Assuming the full cost of inspectors to be $50,000 per year over 220 working days yields a cost of $227 per day, or $3,315 per inspection. Annualizing this inspection cost at a ten percent discount rate gives an annual cost of $332.[28]

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[27]This calculation assumes that the average benefits of each pound of BOD removed due to an inspection equal the nationwide average benefits of the BPT standards. This simplifying assumption ignores the fact that the effluent reductions at some plants induced by inspections will yield benefits much greater than the average, whereas inspections at other plants, even if they result in lower emissions, will improve water quality much less than for an average inspection. Without more disaggregated information about benefits, we were forced to make this simplifying assumption.

[28]The use of a ten percent discount rate is required by the Office of Management and Budget, but other more realistic rates would not significantly affect our conclusions.

Netting this cost of the inspection from the benefits gives an adjusted annualized benefit of $41,876 per inspection.

Consider now whether the annualized compliance costs incurred due to inspections are likely to exceed $41,876 per inspection. Since 75 percent of the firms sampled were already in compliance, we would expect them to spend little or nothing after an inspection. Thus, each non-complying firm must spend at least four times $41,876, or $167,504 per year, in order that the costs associated with a inspection exceed their benefits.

Whether compliance cost exceed this threshold probably hinges on whether the firm must make a capital investment to attain compliance, or whether a change in operating procedures will suffice. Although detailed cost data are not available for all portions of the pulp and paper industry, some suggestive statistics are available with respect to the costs of an activated sluge treatment system used to comply with the BPT standards in the waterpaper-molded products subcategory of the industry.[29]

For concreteness focus on the intermediate plant size (45 kg/day). Compliance for these firms entails an annual operation and maintenance outlay of $113,000, annual energy cost of $19,000, and an annualized capital cost of $339,000, leading to a

[29]While the wastepaper-molded products subcategory is only one of many subcategories in the industry, the activated sludge treatment system represents a standard technology for biological treatment of pulp and paper mill wastes.

total annual cost of $471,000.[30] If compliance following an inspection involves only the operation and maintenance costs, the expenditure of $132,000 is somewhat below the value of benefits less inspection costs. However, if a capital investment is required, the costs exceed the pollution reduction benefits net of enforcement costs by a factor of almost three.

For small plants, with a total annual compliance cost (including amortized capital costs) of $288,000, the compliance costs outweigh benefits once capital costs are included. For large wastepaper molded-products plants with annualized compliance costs of $879,000, even the operation and maintenance costs of $176,000 exceed the pollution reduction benefits.[31]

To the extent that this particular case reflects the costs and the benefits for other subcategories of the pulp and paper industry, the following conclusion holds. If inspections lead firms to make substantial capital investments, then the costs of compliance exceed the benefits. Once having made these investments, firms may be more likely to undertake the appropriate operating procedures to maintain its compliance status as a result of an inspection. This promotion of continued vigilance on the part of firms that have already made the required capital investment is more likely to pass a benefit-cost test.

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[30] All the cost estimates are found in U.S. Environmental Protection Agency, Development Document for Effluent Guidelines and Standards for the Pulp, Paper, and Paperboard and the Builders' Paper and Board Mills (1982).

[31] See U.S. E.P.A., supra, note 9.

VI. Conclusion

Compared with other health, safety and environmental regulations, EPA water pollution regulations for the pulp and paper industry represent an unusual success story. EPA sets standards for which compliance is feasible and then enforces these standards relatively vigorously, with inspections averaging over one per year for our sample. This mix is the opposite of that of OSHA, which has stringent standards coupled with weak enforcement. The coupling of regulations for which compliance is feasible with stringent enforcement is likely to create strong incentives for compliance, and the available evidence bears this out. There is a strong effect of inspections, and their associated enforcement actions, on both pollution levels and rates of compliance with the permit levels. In addition, inspections are associated with less non-reporting on pollutant discharge levels. Judged with respect to its legislative mandate to improve water quality, this effort is clearly a success.

One might raise the more general issue not treated by EPA's enabling legislation of whether the benefits accruing from this pollution reduction are commensurate with their costs. This calculation is in substantial need of better data to refine it, but some preliminary observations are in order. If one includes only the operation and maintenance cost associated with pollution control, then the benefits of inspections may exceed their costs. If capital costs are included as well, the results are probably reversed. One major difficulty associated with this calculation is that we cannot distinguish which incremental pollution control expenditures are associated with the effect of the inspections. Notwithstanding these caveats, it appears that the EPA water pollution regulations represent a dramatic departure from the apparent impotence of most other forms of health, safety, and environmental regulation. Remaining challenge is to set standards at a level that will ensure that the regulations are in society's best interests.